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(57) Abstract

A composition for enhancing combustion of hydrocarbon fuels such as LPG, gasoline and diesel fuel comprises a metal oxide catalyst dispersed in a liquid organic carrier compatible with the fuel. The catalyst preferably includes chromium oxide, magnesium oxide, manganese oxide, cobalt oxide, iron oxide and/or mixtures thereof. The carrier preferably includes Stoddard solvent together with at least one of high temperature lubricant, a surfactant, and a polar organic solvent. The composition permits the fuel to be combusted substantially completely to reduce emissions associated with incomplete oxidation, and to occur at lower temperatures for avoiding formation of NO_x.

FUEL COMBUSTION ENHANCING CATALYTIC COMPOSITION AND METHODS OF FORMULATING AND UTILIZING SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a fuel combustion enhancing catalytic composition, and to methods of formulating and utilizing same. Particularly, the invention pertains to a catalytic additive which is combined with fuel such as LPG, gasoline and diesel fuel, so that the fuels are combusted more efficiently and with less polluting emissions, and to methods of formulating and utilizing the additive.

2. Description of Relevant Art

Applicant has previously sold a combustion enhancing additive particularly useful in carbureted LPG combustion systems for internal combustion engines, such as the engines on fork lifts and the like, which additive is known by the trademark CGX-4®. Such product comprises a blend of a high temperature lubricant, such as a high flash point top oil, at least one detergent or surfactant, and at least one emulsifier, including a polar solvent such as one or more alcohols, in an appropriate organic carrier such as a Stoddard solvent.

SUMMARY OF THE INVENTION

The invention is an improvement of CGX-4® which permits the fuel to be more completely oxidized during combustion in comparison to CGX-4® for improving energy output and decreasing emissions of carbon monoxide, particulates, unburned hydrocarbons and the like, and permits the combustion to be stably carried out at lower temperatures, thereby reducing emissions of nitrogen oxides (NO_x).

The invention provides a composition for enhancing combustion of hydrocarbon fuel, comprising at least one metal oxide catalyst dispersed in a liquid organic carrier

compatible with the hydrocarbon fuel. Preferably the metal oxide catalyst comprises at least one alkaline earth metal oxide or transition metal oxide, and most preferably the metal oxide catalyst is selected from the group consisting essentially of chromium oxide, magnesium oxide, manganese oxide, cobalt oxide, iron oxide and mixtures thereof. The organic carrier preferably comprises a Stoddard solvent. The composition preferably also includes a surfactant, an emulsifier such as a polar organic solvent, and a high temperature lubricant.

The metal oxide(s) function as a catalyst for the combustion of the hydrocarbon fuel, and when added even in very small quantities, e.g., 1-50 ppm, are effective for achieving substantially complete oxidation of the fuel, and for reducing polluting emissions asociated with incomplete oxidation.

Catalytic combustion of the hydrocarbon fuel with metal oxide(s) according to the invention has a large thermal inertia associated therewith, whereby the lower limit of flame stability for the combustion is decreased, permitting lower combustion temperatures to be used and minimizing formation of NO_x emissions.

The invention also provides a method of combusting hydrocarbon fuels, comprising the steps of: combining the hydrocarbon fuel with a dispersion of a metal oxide catalyst in a liquid organic carrier compatible with the hydrocarbon fuel; and combusting the combined hydrocarbon fuel and catalytic dispersion at a maximum temperature below 1500°C. It is preferable that the metal oxide catalyst comprises at least one of a transition metal oxide and an alkaline earth metal oxide, and most preferable that the metal oxide catalyst is selected from the group consisting essentially of chromium oxide, magnesium oxide, manganese oxide, cobalt oxide, iron oxide, and mixtures thereof; that the organic carrier comprises at least one Stoddard solvent; and that the catalytic

dispersion includes a surfactant, a polar organic solvent, and a high temperature lubricant when the combustion process is a carbureted combustion process in an internal combustion engine.

Preferably, said metal oxide catalyst is dispersed in said liquid organic carrier at a ratio of < 1.0 weight %.

An object of the invention is to provide a combustion enhancing catalytic additive for hydrocarbons fuels such as LPG, gasoline and diesel fuel which permits substantially complete oxidation of the fuel to be achieved even when the fuel contains significant quantities of impurities such as free water, propylene, long chain hydrocarbons, etc.

Another object is to provide a combustion enhancing additive for hydrocarbon fuels which substantially reduces or eliminates polluting emissions normally caused by incomplete oxidation, while reducing emissions of NO_x.

Another object is to provide a combustion enhancing additive which can be readily and economically manufactured and combined with hydrocarbon fuels.

Another object is to provide a method of combusting hydrocarbon fuel together with a combustion enhancing additive to reduce emissions of pollutants relating to complete oxidation, and to reduce formation and emissions of NO_x.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The fuel combustion enhancing catalyst according to the invention comprises at least one metal oxide, and preferably at least one metal oxide or transition metal oxide including chromium oxide, magnesium oxide, manganese oxide, cobalt oxide, iron oxide,

and mixtures thereof. These metal oxides are very effective for use as fuel combustion enhancing catalysts because the compounds not only promote total oxidation of hydrocarbons, but also permit the combustion process to be performed at lower temperatures which are not favourable for the formation of NO_x, and they have good thermal stability.

The oxidation process in conventional flame combustion of a fuel such as LPG is a homogeneous reaction taking place in the bulk gas phase. Through introduction of a catalyst in the combustion process, heterogeneous oxidation on the surface of the catalyst also takes place. By the choice of a suitable catalyst it is possible to reduce the activation energy necessary for the heterogeneous catalytic reaction to a level much lower than required for purely homogeneous combustion. For example, for combustion burning of light hydrocarbon fuel such as propane, the activation energy for the uncatalyzed homogeneous oxidation reaction is approximately 25-50 Kcal/gm-mole, but for the heterogeneous catalytic oxidation reaction is approximately 11-15 Kcal/gm-mole. Appreciable heterogeneous (catalytic) oxidation rates can be achieved for temperatures and fuel concentrations much lower than those required for the homogeneous (non-catalytic) reactions to proceed.

In a catalytic combuster, the reaction in the initial part of the combustion bed is primarily catalytic and the rate is controlled by the rate of the surface reaction. As the catalytic reaction increases, the gas and surface temperature and the surface reaction rate constant (which increases exponentially with temperature) quickly becomes so large that the rate of transport of reactants to the catalyst surface becomes the controlling factor for the catalytic reaction. Thereafter, the overall heterogeneous reaction rate is controlled by the mass transfer rate to the catalyst surface. The energy release rate in the mass transfer controlled regime is typically orders of magnitude smaller than those obtainable in the conventional (non-catalytic) flames. At sufficiently high temperatures which are quickly realized in the combustion process, homogeneous reactions are initiated in addition to the heterogeneous catalytic reactions, and the combustion then rapidly goes to completion and energy release rates comparable to conventional flames are achieved.

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When using a metal oxide catalyst dispersion according to the invention, it is possible to conduct combustion of hydrocarbon fuels such as LPG, gasoline, diesel fuel and fuel oil at sufficiently low inlet temperatures and with lean equivalence ratios such that the resulting combustion and exit temperatures of the emissions from the combustion process are sufficiently low that NO_x formation is minimized, and yet combustion is nearly 100% complete so there are low emissions therefrom in relation to incomplete oxidation.

Using an experimental catalytic combuster, the oxides of the alkaline earth metal magnesium and the transition metals chromium, manganese, cobalt, iron and combinations thereof provided the optimum catalytic results. The most active catalyst of these was a binary mixture of chromium oxide and cobalt oxide (Cr_2O_3-Co_3O_4) which gave complete conversion/oxidation of very lean fuel mixtures of LPG and an equivalence ratio of 0.196 at the low inlet temperatures below 850°C. This catalyst mixture was also found suitable for operation over a wide range of equivalence ratios and inlet temperatures in the combustion of LPG; while the NO_x emission index for the LPG combustion using this catalyst never exceeded 0.11 gm/Kg of fuel. Such emission index is significantly smaller (an order of magnitude smaller) than that achieved in conventional LPG combustion systems, including those using applicant's prior combustion enhancing additive.

Using the discussed oxides of alkaline earth metals and transition metals, combustion was complete in some instances and incomplete in others. In cases where complete combustion was achieved, the emission levels of NO_x, carbon monoxide and unburned hydrocarbons were very low. The carbon monoxide and unburned hydrocarbon concentrations were so low that they did not give any reading in gas chromatograph

testing, and the NO_x emission index was always below 0.11 gm/Kg fuel.

Where the combustion was incomplete, typically because of operation under kinetic or mass transfer control/limitations, the chief pollutant was unburned hydrocarbons. Low levels of carbon monoxide were observed in some cases where the exit temperatures were high and combustion incomplete. NO_x emission levels were always very low and found to be strongly temperature dependent, but did not exceed 0.11 gm/Kg fuel.

To combine the metal oxide catalysts with the hydrocarbon fuels, the catalysts are initially dispersed in an appropriate organic medium which is compatible with the hydrocarbon fuel. For LPG fuel, the metal oxide catalysts may be properly dispersed in a Stoddard solvent, and preferably in Stoddard solvent(s) together with a high temperature lubricant, a detergent or surfactant, and a polar molecular solvent such as an alcohol. Only very small quantities of the metal oxide catalysts are necessary to achieve optimum combustion conditions. If the metal oxide catalysts are added in a proportion of 1-50 ppm, and preferably 10-30 ppm, to the hydrocarbon fuel, then complete or substantially complete oxidation/combustion of the fuels can be achieved at sufficietly low inlet temperatures and lean equivalence ratios, whereby emissions of carbon monoxide, unburned hydrocarbons, particulates, and NO_x are all reduced and energy output for a given quantity of fuel is increased. Fine powders of the metal oxides can be dispersed in a Stoddard solvent. Where the metal oxide powders are dispersed in CGX-4®, the detergent/surfactant and/or the polar molecular solvent therein also assist maintaining the metal oxide powder properly dispersed in the organic medium. For example, a dispersion of the metal oxide catalyst(s) containing 0.5-5 weight percent of the metal oxide powder in a Stoddard solvent may be added to CGX-4® in a ratio of 3-5

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volume percent of the dispersion to 95-97 volume percent of CGX-4®, for achieving the combustion characteristics discussed above. The catalytic, modified combustion enhancing additive is then combined with hydrocarbon fuels such as LPG in a ratio of 0.5-2.0 fluid ounces/10.0 gal. Although higher concentrations of the metal oxides catalyst(s) may be added, they do not further enhance the combustion characteristics, while otherwise rendering the catalytic additive more expensive to produce.

The additive is miscible and compatible with LPG fuel, and is easily combined therewith by simply pouring an appropriate amount of the additive into a tank of the LPG fuel, e.g., pouring 1 oz. into a 10 gallon tank, pouring a 55 gallon drum into a 70,000 gallon tank, etc.

The additive according to the invention is particularly effective when used in relation to a carburated LPG fuel system for an internal combustion engine. The additive is also effective for use in relation to other fuels such as gasoline, diesel fuel, fuel oil, etc. and in other types of combustion systems such as non-carburated combustion systems.

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CLAIMS

1. A composition for enhancing combustion of LPG fuel, comprising at least one metal oxide catalyst dispersed in an organic carrier which is compatible with the LPG fuel;

said metal oxide catalyst is a mixture of chromium oxide (Cr_2O_3) and cobalt oxide (Co_3O_4); and

said organic carrier comprising Stoddard solvent, as well as an emulsifier to maintain the metal oxide catalyst dispersed in the Stoddard solvent and in the LPG fuel when added thereto.

2. A composition according to claim 1, wherein said metal oxide catalyst is combined with said LPG fuel at a ratio of 1-50 ppm.

3. A composition according to claim 1, wherein said metal oxide catalyst is dispersed in said liquid organic carrier at a ratio of < 1.0 weight %.

4. A composition according to claim 1, wherein said liquid organic carrier further comprises at least one of a high temperature lubricant and a surfactant.

5. A composition according to claim 4, wherein said liquid organic carrier comprises a top oil having a flash point of at least 400°C. as said high temperature lubricant.

6. A method of combusting LPG fuel, comprising the steps of:

combining the LPG fuel with a dispersion of a metal oxide catalyst in a liquid organic carrier compatible with the LPG fuel; and

combusting the LPG fuel and dispersion at a temperature below 1500°C;

said metal oxide catalyst comprising at least one member selected from the group consisting of an alkaline earth metal oxide and a transition metal oxide; and

said organic carrier comprising Stoddard solvent and an emulsifier to maintain the metal oxide catalyst dispersed in the Stoddard solvent and in the LPG fuel.

7. A method according to claim 6, wherein said metal oxide catalyst is selected from a group consisting essentially of chromium oxide, magnesium oxide, manganese oxide, cobalt oxide, iron oxide, and mixtures thereof.

8. A method according to claim 6, wherein said metal oxide catalyst comprises a mixture of chromium oxide (Cr_2O_3) and cobalt oxide (Co_3O_4).

9. A method according to claim 6, wherein said liquid organic carrier further comprises a high temperature lubricant and a surfactant.

10. A method according to claim 6, wherein said liquid organic carrier comprises a mixture of 3-5 volume percent of a high temperature lubricant, 3-5 volume percent of a surfactant, 1-3 volume percent of said emulsifier; and a balance of said Stoddard solvent.

11. A method according to claim 6, wherein said combustion step is effected in a carburated internal combustion engine.

12. A method according to claim 6, wherein said combustion step is effected using an inlet temperature in a range of 800-1000°C. and at an equivalence ratio in a range of 0.150-0.230.

13. A composition according to claim 1, wherein said metal oxide, catalyst is combined with said LPG fuel at a ratio of 10-30 ppm.

14. A composition according to claim 1, wherein said composition is combined with said LPG fuel in a quantity sufficient to achieve a NO_x emission index for combustion of the LPG fuel of ≤ 0.11 gm/kg of LPG.

15. A method according to claim 6, wherein said dispersion is combined with the LPG fuel in a quantity sufficient to achieve a final concentration of metal oxide catalyst in the fuel of 10-30 ppm.

16. A method according to claim 6, wherein said dispersion is combined with the LPG fuel in a quantity sufficient to achieve a NO_x emission index for combustion of the LPG fuel of ≤ 0.11 gm/kg of LPG fuel.

17. A combustible mixture of LPG fuel and a dispersion of a metal oxide catalyst in a liquid organic carrier compatible with the LPG fuel;

said metal oxide catalyst comprising at least one member from the group consisting of an alkaline earth metal oxide and a transition metal oxide; and

said liquid organic carrier comprising Stoddard solvent, as well as an emulsifier to maintain the metal oxide catalyst dispersed in the Stoddard solvent and in the LPG fuel.

18. A combustible mixture according to claim 17, wherein:

said liquid organic carrier comprises 3-5 volume percent of a high temperature lubricant, 3-5 volume percent of a surfactant, 1-3 volume percent of said emulsifier, and a balance of said Stoddard solvent.

19. A method according to claim 6, wherein said metal oxide catalyst is dispersed in said liquid organic carrier at a ratio of < 1.0 weight %.

20. A combustible mixture according to claim 17, wherein said metal oxide catalyst is dispersed in said liquid organic carrier at a ratio of < 1.0 weight %.